



The NASA Global Hawk UAS and its application for atmospheric science

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Unmanned Aircraft Systems (UASs) provide a new and exciting avenue for atmospheric observations. NASA has a number of unmanned aircraft systems. Among these are the Ikhana (24 hrs., 7000 km range), the Altair (20 hrs., 6500 km), the Aerosonde (30 hrs., 3000 km), and the Global Hawk (30 hrs, 22,000 km). In this poster we describe the upcoming Global Hawk Pacific Mission (GloPac 2009). This mission will be flown on the NASA Global Hawk in the Spring/Summer of 2009. The Global Hawk is a hybrid platform, melding extensive satellite-like geographical coverage with the in-situ capability of a manned aircraft. GloPac 2009 will be the first atmospheric science mission to exploit the long range, extended duration of the Global Hawk. The goals of the mission are to: 1) provide validation observations for NASA satellites, 2) sample the break up of the Arctic stratospheric polar vortex, and 3) observe cross-Pacific transport of aerosols and pollutants such as ozone.

About the Aircraft:

Dimensions:
Wingspan 116.2 ft
Length 44.4 ft
Height 15.2 ft
Width 4.8 ft

Weight:
Payload > 1,500 lbs
Empty weight 9,100 lbs
Take-off fuel 14,500 lbs
Take-off gross weight 25,600 lbs

Propulsion:
Engine AE-3007H Turbofan
Thrust Flat rated at 7500 lbs thrust at sea level

Performance (demonstrated):	Global Hawk	ER-2	WB-57
Maximum Altitude	65,000 ft (20 km)	70,000 ft (21 km)	60,000+ ft (18 km)
Maximum Range	20,000+ km	5,600 km	4,600 km
Maximum endurance	31+ hrs	8 hrs	6 hrs
On-station endurance @ 4,600 nmi	15 hrs		
True airspeed @55 kft+ altitude	172 m/s	210 m/s	210 m/s
True airspeed @25 kft altitude	108 m/s		
Turn radius @ 55 kft+	12 km		

Electrical Power – available to Payloads:
DC (Engine-driven Generator)
AC (Hydraulic-powered Generator)



28 VDC, 72 A (2.0 KW)
115 VAC, 3-phase 400 Hz (8.2 KVA)
(AC converted to 28VDC as needed by payloads)

About the Payload

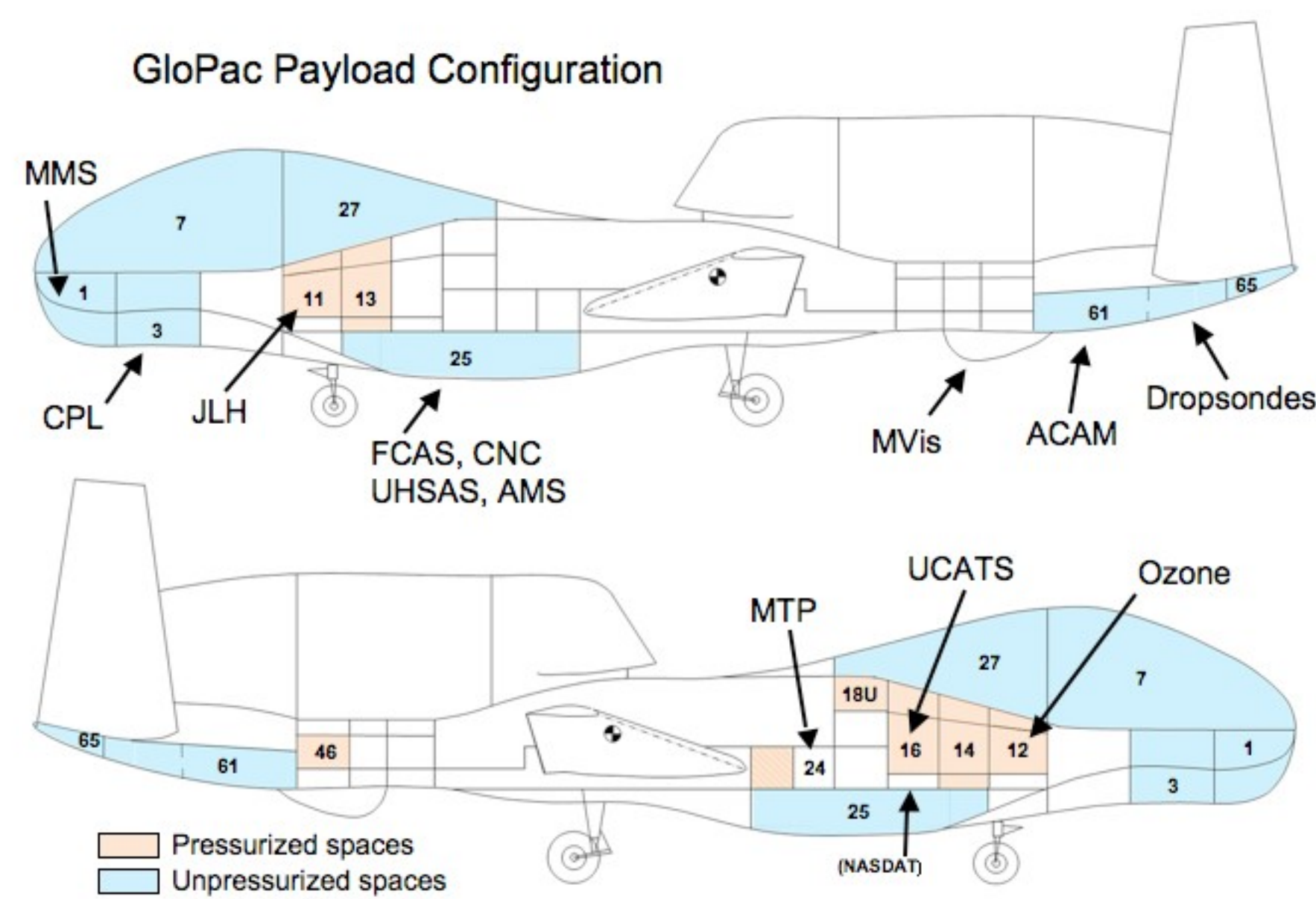
Table 1. Global Hawk *In Situ* Instrument Payload

In situ Instruments	Technique	Payload location	Principal Investigator	Institution
Water vapor (H₂O): JPL Laser Hygrometer (JLH)	Tunable diode laser absorption	Fuselage (Zone 11)	R. Herman	Jet Propulsion Laboratory
Ozone (O₃): NOAA UAS Ozone	UV absorption	Fuselage (Zone 12)	R. Gao D. Fahey	NOAA/ ESRL
Long-lived gases: Unmanned aircraft systems Chromatograph for Atmospheric Trace Species (UCATS) Channel 1: N ₂ O, SF ₆ Channel 2: CO, H ₂ , CH ₄ or CFC-11, CFC-12, Halon-1211	Gas chromatography	Fuselage (Zone 16)	J. Elkins	NOAA/ ESRL
Aerosol particles (0.008 - 2 µm diameter): Condensation Nuclei Counter (CNC)	Supersaturation & growth	Lower fuselage (Zone 25)	J. Wilson	University of Denver
Aerosol particles (0.09 - 1 µm diameter): Focused Cavity Aerosol Spectrometer (FCAS)	Laser scattering	Lower fuselage (Zone 25)	J. Wilson	University of Denver
Aerosol particles (0.05 - 200 nm diameter): Ultra-High Sensitivity Aerosol Spectrometer (UHSAS)	Laser scattering	Lower fuselage (Zone 25)	G. Kok B. Gandrud	Droplet Measurement Technology, Inc.
Aircraft state parameters (pressure, temperature, winds): Micrometeorological Measurement System (MMS)	Aircraft probes and inertial navigation system	Forward fuselage (Zone 1)	P. Bui	NASA Ames

Table 2. Global Hawk Remote Instrument Payload

Remote Instruments	Technique	Payload location	Principal Investigator	Institution
Boundary layer nitrogen dioxide (NO₂) retrieval: Airborne Compact Atmospheric Mapper (ACAM)	Scanning spectrographs & cloud cameras	Rear fuselage (Zone 61)	S. Janz	NASA/ GSFC
Cloud and aerosol properties: Cloud Physics Lidar (CPL)	3-wave-length backscatter lidar	Forward fuselage (Zone 3)	M. McGill	NASA/ GSFC
Vertical temperature profiles: Microwave Temp Profiler (MTP)	Passive microwave sensor	Upper fuselage (Zone 22)	M. Mahoney	Jet Propulsion Laboratory
Atmospheric radiation (infrared and solar emission): Autonomous Modular Sensor (AMS) System	Scanning multispectral sensor system	Lower fuselage (Zone 25)	J. Myers	NASA Ames
Flight path and scene content documentation: MVIS Video Camera	Nadir-viewing color digital video camera	Lower fuselage (Zone 51)	J. Myers	NASA Ames
Under development Pressure, temperature, relative humidity, and wind vertical profiles to the surface: Dropsonde launch system	Release of disposable sondes with pressure, temperature, relative humidity sensors, GPS	Rear fuselage (Zone 61)	D. Fahey T. Hock	NOAA/ ESRL NCAR

GloPac Payload Configuration



Aura Science Validation Goals:

The priorities for Aura validation during GloPac are:

- Measurements in the upper troposphere-lower stratosphere (UTLS) of:
 - Temperature
 - Carbon monoxide (CO) [MLS]
 - Water vapor (H₂O) [MLS]
 - Ozone (O₃) [MLS, TES, OMI]
 - Nitrous oxide (N₂O) [MLS]
- Aerosol size distributions in the UTLS
- Measurements of:
 - Column O₃ [OMI, TES]
 - Sulfur dioxide (SO₂) [OMI]
 - Formaldehyde (HCHO) [OMI]
 - Nitrogen dioxide (NO₂) [OMI]
- Aerosol optical depth and aerosol layer heights
- Cloud height [OMI]

In situ instrument scientific objectives

Water vapor (H₂O) (JLH): Measure water vapor in the upper troposphere and lower stratosphere to (i) validate the Microwave Limb Sounder (MLS) on Aura, (ii) observe the distribution of ice super-saturation in and out of clouds, and (iii) identify and describe transport events in the lower stratosphere such as polar vortex remnants at midlatitudes.

Ozone (O₃) (NOAA UAS Ozone): Provide accurate O₃ measurements in the upper troposphere and lower stratosphere at 2-Hz sampling frequency for use in Aura validation and atmospheric composition and dynamics studies.

Long-lived gases (UCATS): Use measurements to (i) support Aura Satellite Validation of trace gases (N₂O, CFCs, CO, CH₄), (ii) determine age-of-air in the lower stratosphere (using SF₆), (iii) estimate the total organic and inorganic chlorine and bromine budgets in the lower stratosphere, (iv) identify transported air containing Asian air pollution (using SF₆, CO, O₃, CFCs, halons), (v) identify polar vortex fragments (using N₂O, CFCs, CH₄), and (v) identify air that has been transported across the tropopause (N₂O, CFCs, CH₄).

Aerosols (CNC, FCAS, UHSAS): Measure particle size distributions in the upper troposphere and lower stratosphere to understand the roles of transport, new particle formation, removal by clouds in determining the aerosol abundance, (ii) study the variation with location of aerosol properties and their controlling processes, (iii) characterize the particle population that provides nuclei for cloud formation in the UT, and (iv) observe particle size distributions in pyro-cumulus plumes in the UT/LS.

Aircraft state parameters (MMS): Provide science-quality state variables (pressure, temperature, winds) to (i) compare with meteorological forecasts and analyses, (ii) constrain calculations of kinetic parameters, (iii) compute saturation conditions for water, nitric acid, sulfuric acid, (iv) identify gravity wave structures in the upper troposphere and lower stratosphere, and (v) provide state parameters for other in situ instruments.

Remote instrument scientific objectives

Boundary layer NO₂ retrieval (ACAM): Provide (i) spatial scaling of boundary layer NO₂ plumes to support validation of the Aura OMI and model studies of the next-generation geostationary satellite sensors, and (ii) NO₂ diurnal variability for model improvement for next-generation geostationary sensors.

Clouds and aerosol properties (CPL): Provide high-altitude profiling of the vertical structure of aerosols and clouds, (ii) identify cloud-free/elevated aerosol-free regions, (iii) identify type, height, coverage, and composition of clouds, (iv) validate Aura OMI aerosol optical depth and cloud height retrievals, and (v) validate Aura HIRDLS and MLS retrievals of cloud/aerosol height and cloud phase.

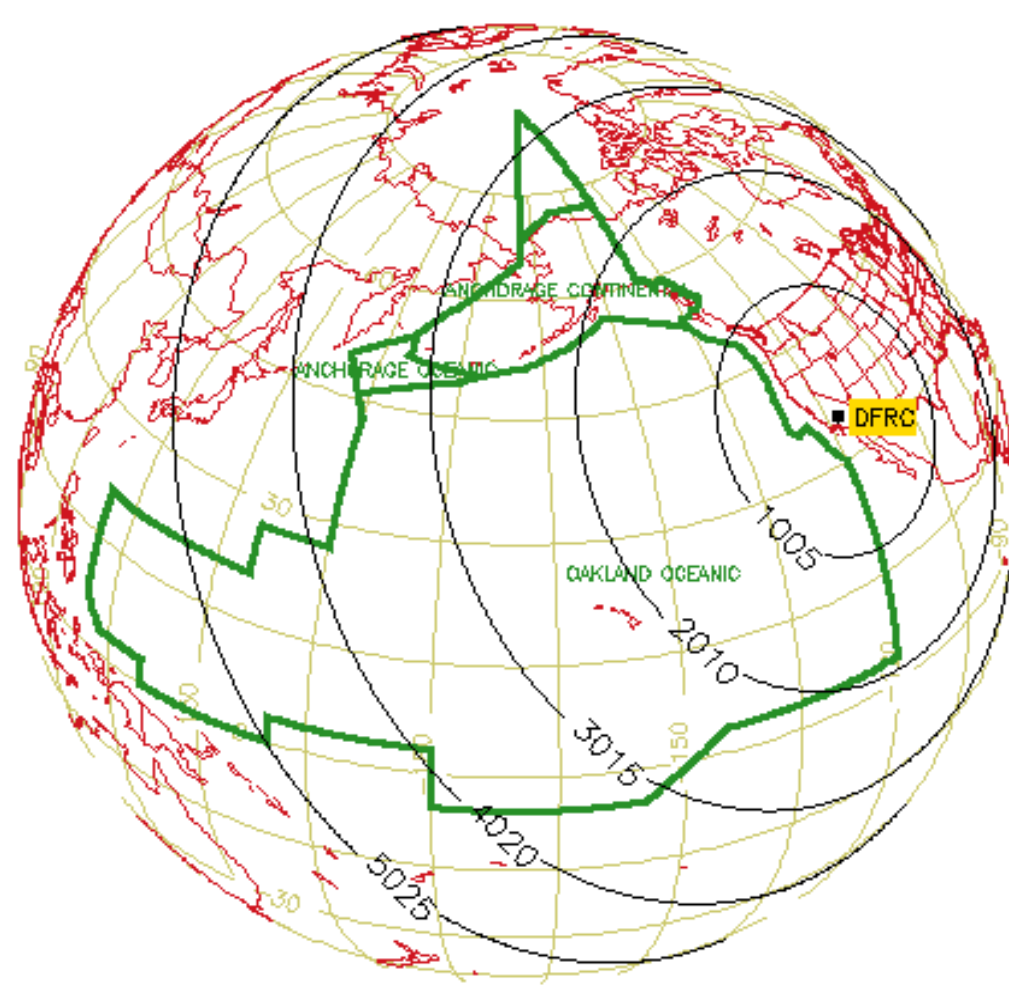
Temperature profiles (MTP): Provide accurate vertical temperature profiles that can be used to (i) define the meteorological context along the flight track (e.g., aircraft location with respect to the tropopause) for other onboard measurements of trace gases and aerosols, (ii) validate temperature profile measurements made by Aura MLS and TES instruments, (iii) identify isentropes (i.e., surfaces of constant potential temperature) from the temperature curtain along the Global Hawk flight track so that atmospheric dynamics can be studied and transport pathways can be identified.

Atmospheric radiation (AMS): Provide (i) spatial maps of infrared emission and solar reflection, (ii) the spatial distribution of upper tropospheric and total water vapor (6.7 µm band), (iii) (under development) cloud micro-physical properties, using GSFC MODIS-MAS algorithms (optical thickness, effective radius, etc), (iv) horizontal structure of atmospheric aerosols, and (v) sub-visible cirrus.

Flight path documentation (MVIS): Provide flight path and scene content documentation along the flight track.

Pressure, temperature, and wind profiles (Dropsonde Launch System) (Under development): The dropsonde units will measure key meteorological and state variables in a vertical profile to the surface below the aircraft launch point (pressure, temperature, relative humidity, horizontal winds). These data will be used in a variety of ways: climate change detection, hurricane reconnaissance, atmospheric river forecasting, and satellite calibration and validation activities.

Area of Operations



Flights of unmanned aircraft face restrictions over populated areas, so most of the flights for GloPac will be over the ocean. To simplify interactions with air traffic control authorities, flights will generally take place within the aviation administrative area (Flight Information Area, or "FIR") known as "Oakland Oceanic", shown here in dark green. Also shown are range rings centered about NASA's Dryden Flight Research Center (DFRC), spaced 1005 nautical miles apart (approx. 1860 km), or about every three hours of flight time. The 5025 nmi circle corresponds to 15 hours one-way, or a 30-hour round trip.

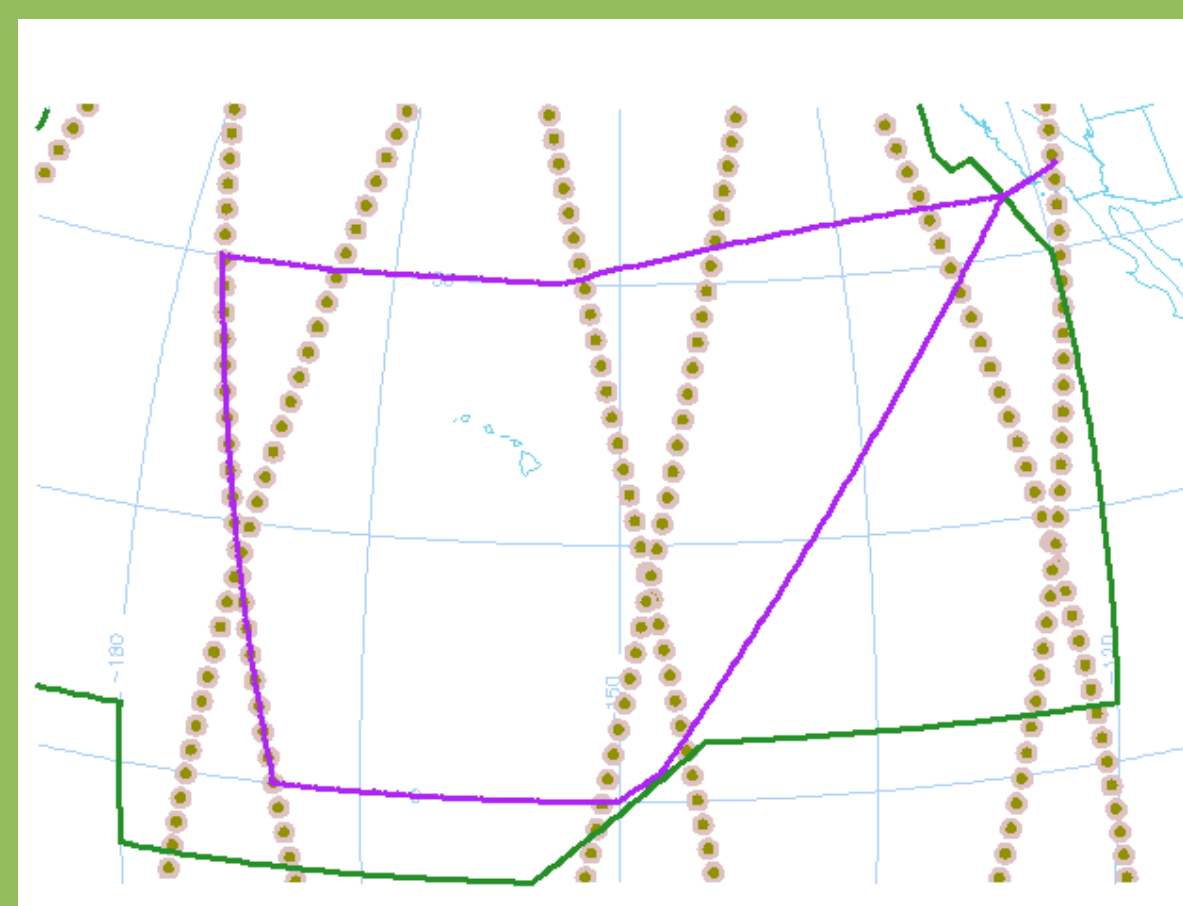


NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/Gallery/Photo/index.html>
NASA Photo: ED07-0244-78 Date: December 3, 2007 Photo By: Tony Landis

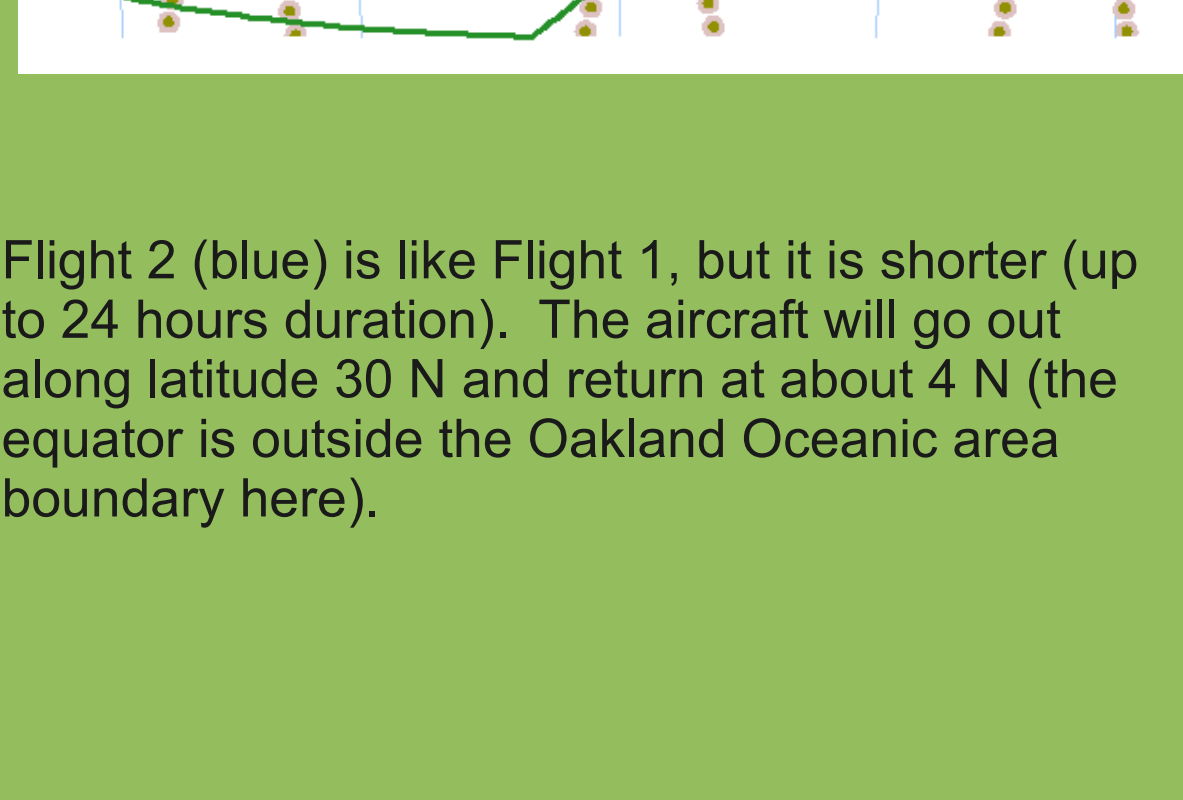
In its new white-and-blue NASA livery, an early development model of the Global Hawk unmanned aircraft rests on the ramp at the Dryden Flight Research Center.

Sample GloPac Flights

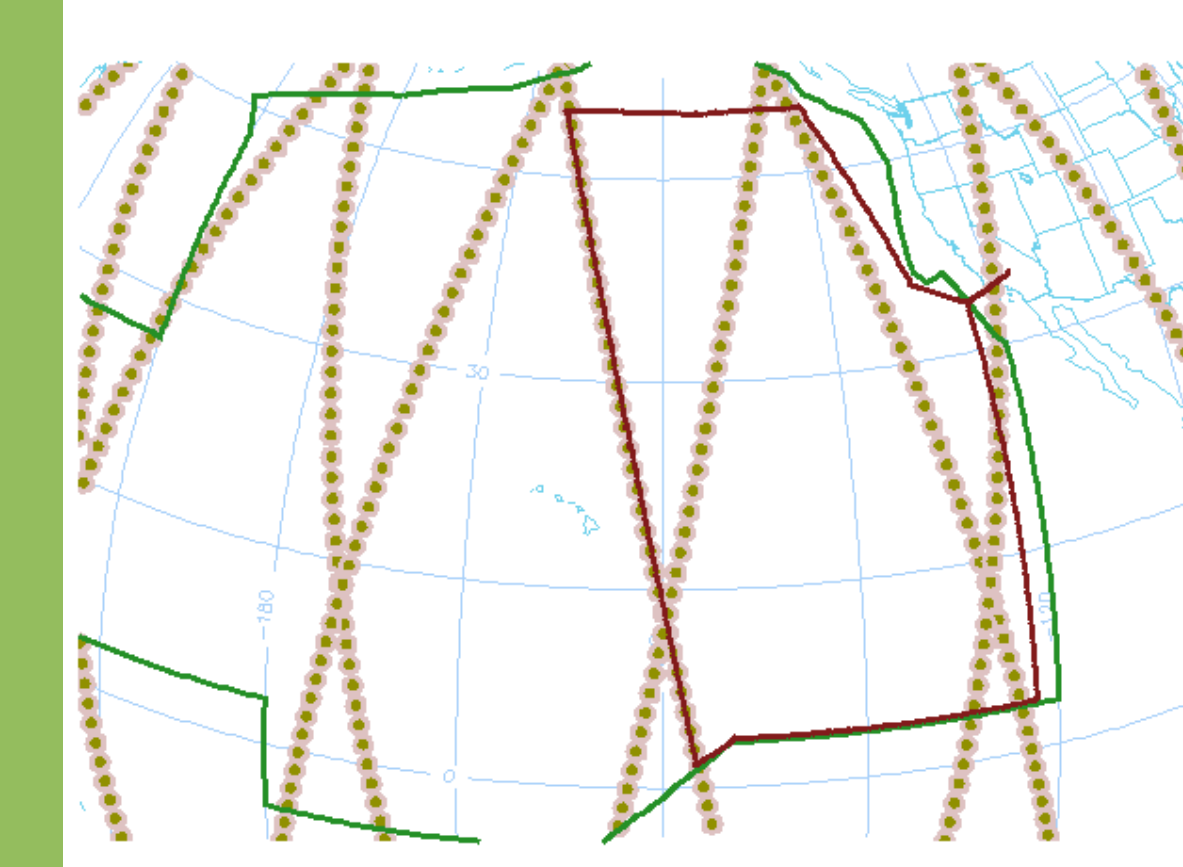
Six basic flight paths are shown below. The first five are designed to follow Aura or A-Train satellite sampling tracks, and the sixth is a flight into the polar region. The Aura Microwave Limb Sounder (MLS) sampling points are shown as gray-and-yellow dots; FIR boundaries (Oakland Oceanic) are shown in dark green. Interception flight tracks are shown for a maximum-duration flight. Each flight includes one to three descents to 45,000 ft (~ 14 km) for vertical profiling in situ. Which flight gets flown on a given date will be determined by the overall dynamical situation as well as operational concerns. (The first flights will be 24 hours or less, with the full 30-hour flights coming later in the mission.)



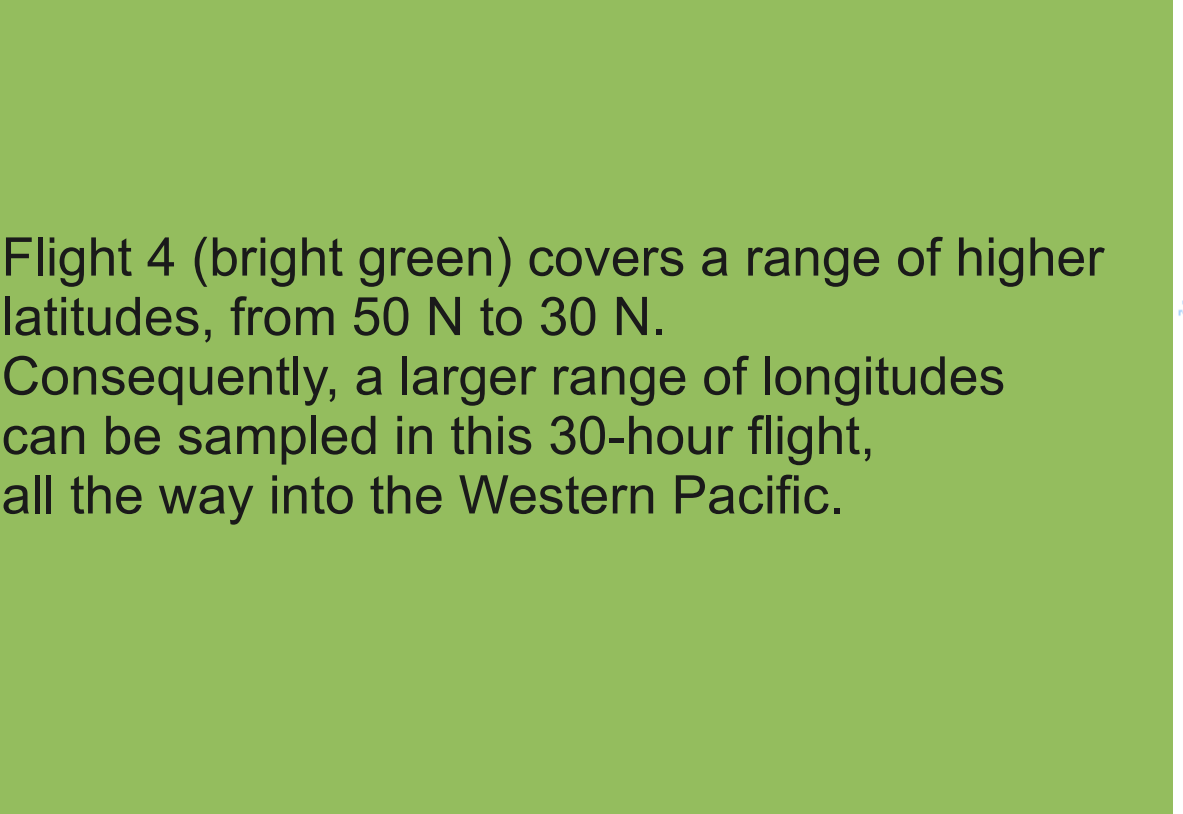
Flight 1 (purple) is typical of these flight plans. The aircraft heads out along one latitude (30 N) until it intercepts an MLS track (or other Aura or A-train track). It follows the track until it reaches the equator, which it then follows for a while before heading home. Total flight time is up to 30 hours. The along-track portion of the flight will be adjusted to intercept the track for the flight day.



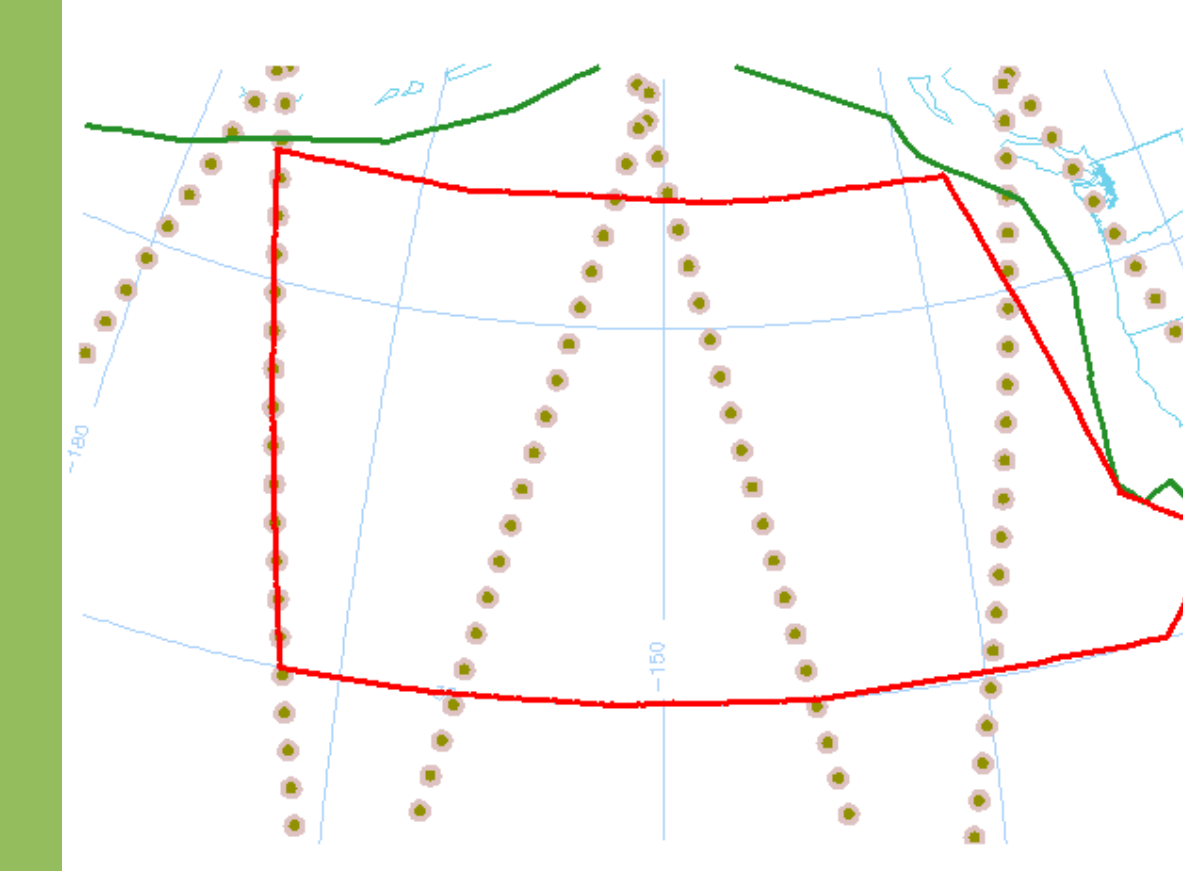
Flight 2 (blue) is like Flight 1, but it is shorter (up to 24 hours duration). The aircraft will go out along latitude 30 N and return at about 4 N (the equator is outside the Oakland Oceanic area boundary here).



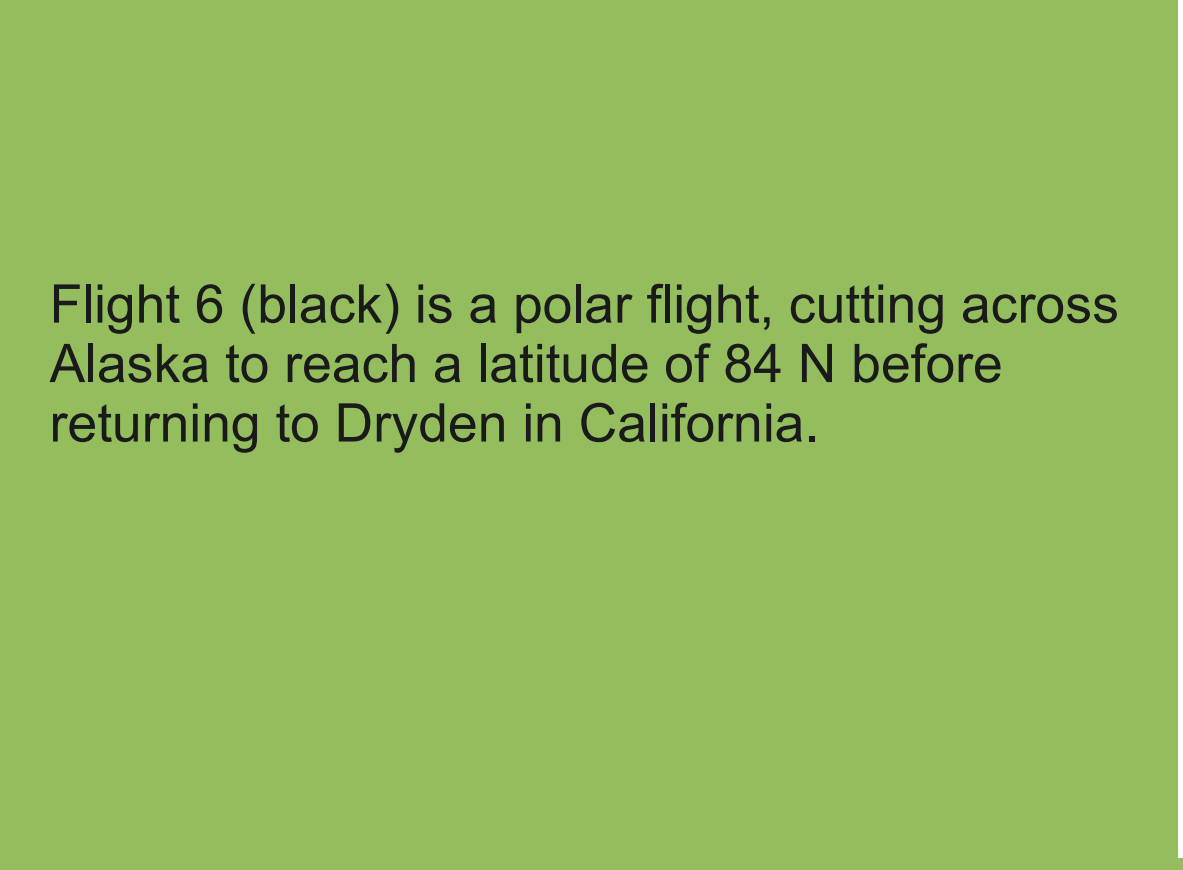
Flight 3 (brown) is back to a 30-hour flight, but it trades longitudinal range for latitudinal range. Unlike Flight 1, it no longer reaches into the mid-Pacific, but its latitude legs are now at 50 N and 4 N.



Flight 4 (bright green) covers a range of higher latitudes, from 50 N to 30 N. Consequently, a larger range of longitudes can be sampled in this 30-hour flight, all the way into the Western Pacific.



Flight 5 (red) is like Flight 4, except it is cut short to stay under 24 hours in duration.



Flight 6 (black) is a polar flight, cutting across Alaska to reach a latitude of 84 N before returning to Dryden in California.